REVIEW

Surgery for morbid obesity

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The prevalence of morbid obesity in the UK population is rising, bringing with it increased levels of cardiovascular disease, diabetes, arthritis and early mortality. The overall cost to the health service is high, and is set to increase over the coming decades as the overweight population ages. Dietary, lifestyle and pharmacological interventions offer at best reasonable, short-term weight reduction and often fail. Surgical intervention is a safe and effective means of delivering marked long-term weight reduction. This article compares and contrasts the options available for surgical treatment of morbid obesity based on a review of the current literature.

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The past 20 years has seen a doubling in the worldwide prevalence of morbid obesity.[1] In 2002, the National Institute for Health and Clinical Excellence (NICE) estimated that there were 1.2 million morbidly obese people in England and Wales, and that this number would increase by 5% per annum. Morbid obesity is associated with twice the mortality compared with the general population, and with other conditions such as hypertension and type II diabetes, as well as increased levels of psychiatric illness. There is also a considerable strain on healthcare resources and society as a whole, and this cost is set to rise as the general population becomes more obese. The aetiology of morbid obesity is complex, involving the interaction of psychosocial, genetic, endocrine and metabolic factors, making conservative treatment difficult and prone to failure. Surgery is more invasive, but is the only means of achieving considerable and sustained weight loss—a rapidly increasing priority in UK medical practice.

Metabolic effects of morbid obesity

The most common method of assessing obesity is the body mass index (BMI; mass (kg)/height (m^2)). Both NICE and the National Institute of Health (Bethesda, Maryland, USA) define morbid obesity as a BMI of $\geqslant$40 kg/m^2, or $\geqslant$35 kg/m^2, along with one of the comorbidities shown in the box.

Many of the comorbidities listed in the box result from the metabolic effects of obesity. The so-called ''metabolic syndrome'' becomes more common with rising BMI, and carries a threefold increase in cardiovascular morbidity. Polycystic ovary disease, the most common chronic disorder in women, is also more prevalent in this population. Morbid obesity is also associated with severe venous stasis, degenerative joint disease, gout, cholelithiasis, urinary stress incontinence and pseudotumour cerebri. Further, non-alcoholic fatty liver disease is present in 90% of liver biopsy specimens taken during bariatric surgery, with non-alcoholic steatohepatitis diagnosed in 25% of patients.[2]

Many of these comorbidities have been shown to improve, and several to resolve completely, after considerable weight reduction. Morbid obesity not only increases the risk of metabolic and physiological abnormalities but is also closely associated with increased levels of depression and anxiety.[3 4] When compared with those having chronic medical conditions, obese patients rate their health-related quality of life as considerably worse.

Treatment options for morbid obesity

The three main treatment options for morbid obesity are lifestyle change, pharmacotherapy and surgery. Lifestyle change should involve restriction of calorie intake with increase in exercise so that moderate weight loss can occur in the short term. However, up to 66% of patients regain weight within 24 months and long-term results are poor.[5–7] Studies have shown that pharmacotherapy through sibutramine, orlistat or phentermine is more effective, and greater weight loss has been shown to occur compared with lifestyle interventions alone.[8 9] Drug treatment is probably most beneficial when used in conjunction with a suitable weight-management programme. Further, these drugs also have other beneficial effects on lipid levels, blood pressure and insulin resistance beyond that expected from their effects on weight loss alone.[6] Despite short-term success, weight loss is usually not maintained, and up to 90% regain weight on cessation of treatment. In addition, there are reports of side effects (including hypertension, tachycardia and bowel disorders) that preclude their broad usage.[9 10]

Bariatric surgery offers the only means of delivering sustained weight loss. Over 50% excess weight loss (EWL) can be achieved after surgical intervention, and these results are sustained at 10–15 year follow-up. The Swedish Obese Subjects study comparing surgical, pharmacological and lifestyle interventions showed a clear benefit for surgery at 10 years, with an average weight loss of 16% in the surgical arm compared with 1.6% weight gain in the non-surgical arm.[11–13] In addition, a meta-analysis performed by Buchwald *et al*[14] showed a weight loss of 61.2% of excess weight after surgical intervention.

Abbreviations: BMI, body mass index; BPD, biliopancreatic diversion; EWL, excess weight loss; LAGB, laparoscopic gastric banding; NICE, National Institute for Health and Clinical Excellence; RYGBP, Roux-en-Y gastric bypass; VBG, vertical banded gastroplasty

Box: NICE guidelines—comorbidities associated with morbid obesity

- Cardiovascular disease
- Hypertension
- Type II diabetes mellitus
- Osteoarthritis
- Reproductive disorders (infertility)
- Respiratory disorders (sleep apnoea)
- Cancers (endometrial/ovarian)

Comorbidity resolution after bariatric surgery occurs in 75–90% of cases, particularly for insulin resistance, hypertension and respiratory disorders.[12 14–16] The effects of sustained weight reduction on the lifetime risk of developing obesity-related conditions have been quantified by Cristou *et al*[17] in a large Canadian cohort study. After 5 years, the relative risks of developing cardiovascular, endocrinological (including diabetes), musculoskeletal, genitourinary, psychiatric, respiratory and haematological disorders were markedly reduced. Further, the relative risk of developing cancer in the surgical cohort was 0.21 after surgery compared with non-operated morbidly obese subjects over the 5-year period.

The number of bariatric procedures performed worldwide has increased considerably over the past few years. This review discusses why surgery is now having a greater role in the treatment for morbid obesity. Each of the available procedures is discussed, in turn followed by a systematic comparison of the largest case studies to compare safety and efficacy.

SURGERY FOR MORBID OBESITY

The ideal surgical intervention for morbid obesity should be effective, safe and applicable to all patients. It must achieve considerable weight loss and resolution of comorbidity. Low operative morbidity and mortality is essential, with a short hospital stay and rapid return to normal activity desirable. All patients undergoing a bariatric procedure require meticulous follow-up. A multidisciplinary team incorporating dieticians, psychiatrists and endocrinologists should always be available both for advice and to deal with any problems that arise.

Current surgical practice can be divided by the mechanism of weight reduction: restrictive by decreasing the storage capacity of the stomach, malabsorptive through surgical bypass thus excluding intestinal loops, or a combination of the two.

RESTRICTIVE PROCEDURES

Vertical banded gastroplasty

Vertical banded gastroplasty (VBG) was originally described by Mason in 1982,[18] and involves the placement of a 5 cm band around a gastric pouch created by stapling the gastric fundus (fig 1). The procedure is most commonly performed laparoscopically because of the improved wound, pulmonary and thromboembolic complication rates. It takes around 1½ h to perform, with a hospital stay of approximately 5 days. Satisfactory levels of weight loss can be achieved, with one trial documenting >50% EWL in 74% of patients.[19] In most series with 3 to 5-year follow-up, EWL of ⩾50% has been achieved in only 40%.[20 21]

Mortality is <1% in most studies, with an overall morbidity of 14%.[12 15 21–23] Complications include stomal stenosis (20%), staple line disruption (11%), severe oesophagitis (7%) and band migration (1.5%).[24] Patients can often complain of intolerance to solid food coupled with persistent vomiting. This leads to a prolonged hospital stay. Occasionally, surgical revision is the only solution.

Vertical banded gastroplasty, open and laparoscopic, has produced good results for both weight loss and comorbidity, but comparable or better results are achieved with either adjustable gastric banding or gastric bypass. Both of these latter procedures also seem to have better side effect profiles, and this has led to a shift towards use of the gastric band as the restrictive procedure of choice.

Adjustable gastric banding

Laparoscopic gastric banding (LAGB) is by far the most popular restrictive bariatric surgical intervention in Europe and Australia, and is rapidly gaining popularity in the US after receiving approval from the Food and Drug Administration in 2001. Developed by Belachew[25] in 1992, to date over 250 000 gastric bands have been placed worldwide. The procedure involves the placement of an inflatable band to form a 15–20 ml superior gastric pouch, with band position reinforced by the placement of anterior gastro-gastric sutures. The band connects to a self-sealing reservoir (Portacath) implanted beneath the skin. This allows for adjustment of the stoma diameter to increase or reduce the rate of passage of food from the upper pouch into the body of the stomach (fig 2). The sensation of satiety caused by the distension of the gastric pouch leads to early meal termination, and hence reduced calorie intake. Patients also report prolonged post-meal satiety, paradoxically as they have markedly reduced energy intake, which further decreases their calorie intake. The mechanism by which this occurs is still not understood.[26] Band placement takes 30–60 min, with a conversion rate of around 1%. Patients remain in hospital for around 24 h and return to normal activities within 1 week.[27–29]

Laparoscopic banding can achieve a mean EWL of approximately 50% in the short term (1–2 years), which continues in the long term.[30–34] Both Steffen (n = 824)[35] and Zinzindohoue (n = 500)[29] have shown an EWL of ⩾50% in 80% of their patients at over 3 years follow-up. After LAGB, the main obesity-related comorbidities (hypertension, diabetes, respiratory disease and osteoarthritis) also improve markedly, with some studies showing complete resolution.[29 36 37] Further, banding has been successful in the treatment of the super obese (those with a BMI >50 kg/m^2), achieving >50% EWL and 90% comorbidity resolution, with lower postoperative morbidity and mortality than other alternative bariatric procedures.[28 36 38 39] Laparoscopic banding is the safest bariatric surgical procedure, with a postoperative mortality of <0.5%.[40–42] Many studies have shown a considerably lower incidence of complications after LAGB compared with alternative procedures, and these conclusions are supported by both the Australian Safety and Efficacy Register of New Interventional Procedures-Surgical and NICE.[24 28 39 43–45] Further, a single-centre study of the three main surgical interventions has shown a markedly (3.5 times) lower level of overall and severe complications for LAGB compared with either laparoscopic Roux-en-Y bypass or laparoscopic biliopancreatic diversion.[46]

Procedure specific complications include band slippage, band erosion, oesophageal dilatation and Portacath migration. Slippage (herniation of the stomach superiorly through the band) can cause partial or total gastric obstruction, and often requires surgical correction. An early series reported slippage rates of 12–24%, but by adopting a pars flaccida approach for band placement (dissection outside the lesser sac)[46 47] in conjunction with application of anterior gastro-gastric sutures and by delaying the inflation of the band, the incidence has been reduced to 1–2%.[47 48] Band erosion prevalence is <2% in a larger series,[49] and is commonly caused by gastric microperforation or by oversewing of the band's buckle. Another problem is

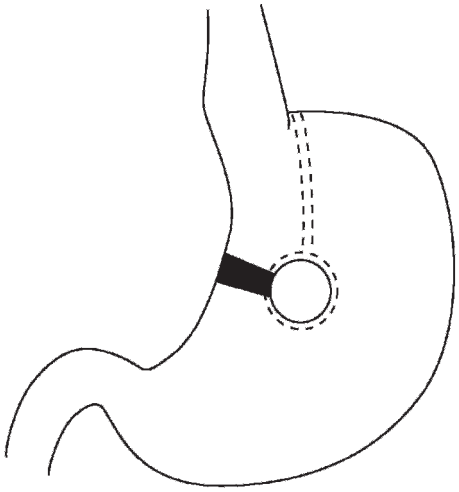

Figure 1 Vertical banded gastroplasty.

oesophageal dilatation/dysmotility, which can often remain asymptomatic. The true incidence is unknown, as regular contrast studies are required to monitor for occurrence.[50] However, the condition seems to resolve fully on band deflation.[16 51] Portacath-related problems occur in around 7.5% of cases. Studies have shown that complications generally reduce in incidence with increasing experience of the surgeon, and all can be treated safely either by minimally invasive or by local anaesthetic procedures. Technical complications such as band puncture during gastro-gastric suturing may also potentially occur, but become very rare with increasing surgical experience.[13 52 53]

The disadvantage of LAGB, as with all bariatric surgical procedures, is that it is not effective in everyone. LAGB is therefore best performed in a multidisciplinary unit, so that patients can receive professional support before and after surgery, with access to regular follow-up and band adjustment to ensure optimum weight loss.[54] Some patients, however, inevitably require a second procedure. Laparoscopic conversion or reversal of LAGB is safe,[40 55] with low operative mortality (0%) and morbidity (14.3%); conversion rates are comparable to those for the primary procedure.[56] Weiner's[40] experience with nearly 1000 bands confirms that laparoscopic removal of the band or laparoscopic conversion to an alternative procedure carries a low mortality and morbidity, with duration of hospital stay similar to that for the primary procedure.

LAGB has proved itself fast, effective and safe in the treatment of morbid obesity. It achieves a gradual, controlled and adjustable reduction in weight, with excellent results at 2–3 years. Weight loss is sustained in the long term. It has a short learning curve, and markedly lower mortality/morbidity than alternative procedures. It does fail to achieve sufficient weight loss in a small proportion of cases, and these then require conversion to an alternative, usually malabsorptive, procedure.

MALABSORPTIVE PROCEDURES

Jejunoileal bypass

Jejunoileal bypass was the first widely performed operation for obesity. The procedure entailed excluding most of the small bowel, by leaving just 30 cm of the jejunum and 10 cm of the ileum in continuity. Although successful in causing weight loss, it is now a defunct procedure for the treatment of morbid obesity, owing to a severe side effect profile. The procedure did achieve sustained weight loss in 70% of patients,[57] but the long-term complications of liver failure (10%), urolithiasis (29%)

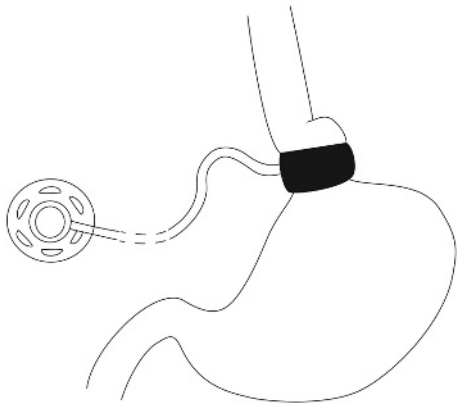

Figure 2 Laparoscopic adjustable gastric banding.

and renal failure (9%) have led to its abandonment.[58] Many of the 25 000 jejunoileal bypasses performed in the US have since been converted to gastric bypass.

Biliopancreatic bypass with or without duodenal switch procedure

Biliopancreatic diversion is often the procedure of choice for patients with very high BMI (>60 kg/m^2) owing to its impressive weight loss profile. Its widespread use is limited by a more severe side effect profile and higher mortality compared with alternative procedures. First reported in 1979,[59] BPD involves the formation of a distal gastrectomy with a proximal 200–500 ml gastric pouch and a long Roux-en-Y reconstruction. The ileum is divided 250 cm from the ileocaecal valve and an enteroenterostomy fashioned 50 cm from the ileocaecal valve, thus forming a 200-cm alimentary limb (anastomosed proximally to the stomach) and a 50-cm common channel (fig 3). The operation results in inadequate digestion inside the short common limb.

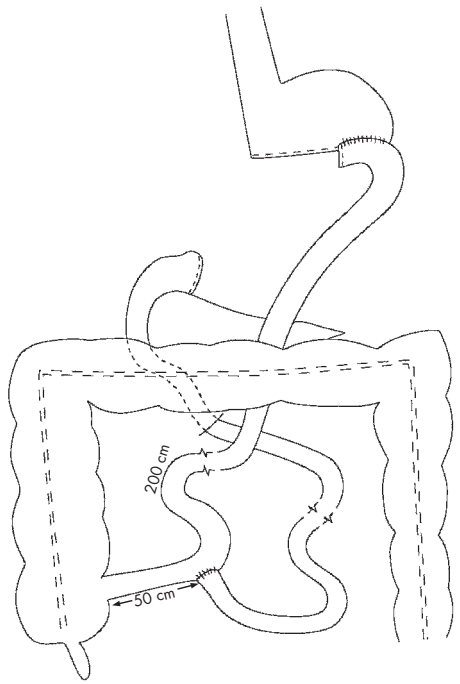

Figure 3 Biliopancreatic diversion.

Because of the frequency of stomal ulceration and unpleasant dumping syndrome with biliopancreatic diversion, the duodenal switch procedure, involving a sleeve gastrectomy and preservation of the pyloric sphincter, was developed with marked success (fig 4).[60 61] The restrictive component is short lived, so that appetite and eating capacity are restored to preoperative levels within 1 year. Long-term weight loss is achieved mainly through malabsorption.[59 62]

Operation time for the open procedure can be >3½ h during the learning curve, but averages 2½ h in experienced hands.[63] Postoperative hospital stay is longer than for other bariatric procedures, befitting a large open surgical procedure, and there is a considerable recuperation period before return to normal activities. The laparoscopic approach, introduced in 2001, benefits from reduced wound complications, with equivalent non-wound-related morbidity and shorter hospital stay, although operation time is considerably longer.[59 64]

Scopinaro published two large Italian series of 1356 and 2000 BPDs reporting EWL of 74–78% and 73–78%, respectively. These results have been supported by several smaller series.[59 65 66] Follow-up at 15 years has shown little or no weight regain (table 1). Further, weight loss is associated with high rates of comorbidity resolution, particularly for diabetes and hypertension.[59 63] Failure to achieve or maintain sufficient weight reduction, up to 15% in some series, requires re-operation to modify limb length or the addition of a greater restrictive component.[67 68]

Published mortality for BPD with duodenal switch is around 1%. Early wound-related complications occur in 1.5%, with the incidence of incisional hernia 25% (for open surgery). Respiratory complications occur in 0.4% and stomal ulceration in 8.3% of patients (for patients having BPD without duodenal switch). Further, protein calorie malnutrition can also occur in many and may require a period of parenteral feeding. Despite mineral and vitamin supplementation, persistent anaemia occurs in a considerable proportion of patients and bone demineralisation is also common.[59 69 70] Finally, the development of severe metabolic complications may necessitate surgical revision—a technically simple procedure, but one carrying high surgical morbidity and risk of weight gain.[71]

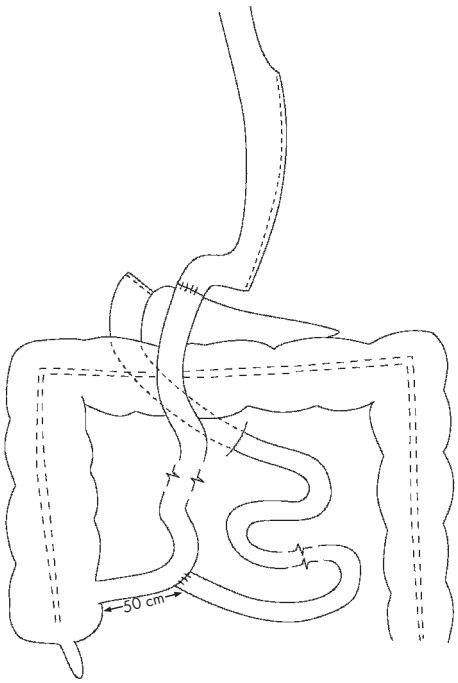

Figure 4 Biliopancreatic diversion with duodenal switch.

The poor side effect profile, increased operative time and longer hospital stay compared with other bariatric procedures would seem to restrict its use to patients in whom other interventions fail. Although few centres perform this procedure, BPD may have a role as part of a two-stage procedure, with an initial sleeve gastrectomy and follow-up BPD once a proportion of weight has been lost. This approach may be particularly useful in the super obese (BMI >50 kg/m^2), and has recently been shown to be both safe and effective.[72]

COMBINED RESTRICTIVE AND MALABSORPTIVE PROCEDURES

Gastric bypass

This procedure was first described by Mason and Ito in 1967,[73] and integrates restriction with altered absorption. The Roux-en-Y gastric bypass (RYGBP) is now the most common bariatric procedure performed in the US. The procedure involves the formation of a 15–20 ml gastric pouch and the fashioning of a Roux-en-Y gastrojejunostomy bypassing the distal stomach, duodenum and a variable length of proximal jejunum (fig 5). This effectively reduces the size of meal that the patient is able to ingest. Additionally, the bypass causes some degree of malabsorption. Operating time for the open procedure is approximately 100 min, but this rises to 140 min if the procedure is performed laparoscopically.[74] A hospital stay of 5 days, and several weeks to fully recover, is to be expected after open bypass,[43] but both are markedly reduced if the laparoscopic approach is successful.[27]

Gastric bypass achieves excellent initial weight reduction, with a mean EWL of nearly 70% at 1 year.[14] A number of case series have shown that after 3 years 60–70% of patients can achieve >50% weight loss.[44 57 75–77] Long-term results are good, with an average EWL of 60% at 5 years, but this decreases to around 50% at 8–10 years.[78 79] Gastric bypass is also effective in the treatment of ''super'' obese patients with a BMI of ⩾60 kg/m^2.[80] As with all bariatric procedures, it carries a risk of failure, with 15% of patients failing to achieve or maintain an EWL of >50%.[81] Revisional surgery is complex and carries significant risk, with options including increasing malabsorption (conversion to BPD or increasing limb length) or application of further restrictive procedures such as the lap-band.[82]

Bypass surgery carries a mortality of approximately 0.5% for both the open and laparoscopic approaches. Wound related and pulmonary complications are comparable to alternative open surgical interventions. Studies have shown that the laparoscopic approach offers a reduction in critical care requirement, postoperative pulmonary complications and incidence of incisional hernia.[74 83 84] However, the most serious complication with this operation, anastomotic leak, occurs in 2–5% of open cases,[81] but possibly at a higher rate after laparoscopic bypass.[85] It is thus important that the surgeon embarking on laparoscopic RYGBP has sufficient expertise to master the technical demands of the procedure. Studies have also shown that gastro-gastric fistula, small bowel obstruction and internal herniation are also more prevalent after laparoscopic bypass.[83 84] Marginal ulceration (at the gastrojejunostomy site) has been reported at 3%, and responds to pharmacological treatment in most of the cases.[43 86] Long-term vitamin and mineral deficiency, although more amenable to supplementation than in BPD, can still necessitate surgical revision.

Open and laparoscopic gastric bypass can deliver both significant weight loss and resolution of comorbid conditions, although on failure, it requires further intervention, carrying significant risk. The laparoscopic approach has become more popular, with its reduced incidence of postoperative wound,

Table 1 List of published studies reporting >500 bariatric procedures

Authors	Year	Procedure	No of patients	BMI	Early complication rate (%)	Late complication rate (%)	30-day mortality (no of patients)	Weight loss data (mean %EWL unless otherwise stated)					
								1 year	2 years	3 years	4 years	5 years	>5 years
Szold and Abu-Abeid[92]	2002	LAGB	715	43.1	1.9	10.3	0	Mean BMI improved to 32.1 (at 30 months)					
Parikh[38]	2005	LAGB	749	46	12.8	10.1	0	44.4	51.8	52	–	–	–
Vertruyen[33]	2002	LAGB	543	44	2.2	10.8	NS	38	61	62	58	53	52 (7.2years)
Chevallier[46]	2004	LAGB	1000	44.3	2.2	19.3	0	–	–	–	–	–	–
Dargent[93]	1999	LAGB	500	43	2.2	6	0	56	65	64	–	–	–
Favretti[94]	2002	LAGB	830	46.4	0.2	3.7	0	70.4% had EWL >30 at 3 years					
Cadiere[95]	2002	LAGB	652	45	0.6	7.2	1	38	62	–	–	–	–
Belachew[32]	2002	LAGB	763	42	2.2	13.8	1	40	50	–	55	–	–
Angrisani[41]	2003	LAGB	1893	43.7	10.2	10		33.7	34.8	34.1	32.7	34.8	–
Zinzindohoue[29]	2003	LAGB	500	44.3	2.8	16	0	42.8	52	54.8	–	–	–
Ceelen[96]	2003	LAGB	625	40	4.3	7.4	0	45.8	49.9	47.4	–	–	–
Steffen[35]	2003	LAGB	824	43	1.2	23.2	0	29.5	41.1	48.7	54.5	57.1	52 (7.2years)
Weiner[40]	2003	LAGB	984	46.8	0.2	6.5	0	–	–	–	–	–	59.3 (8.2years)
Biertho[42]	2003	LAGB	805	42.2	3	9.1	0	33	–	–	–	–	–
Fernandez[97]	2004	LAGB	580	49.1	7	NS	4	NS					
Fernandez[97]	2004	Open gastric bypass	1431	53.3	7	NS	27	NS					
McCarty[98]	2005	Lap RYGB	2000	49	1.9	4.25	2	NS					
Shikora[99]	2005	Lap RYGB	750	47	15.1	NS	2	NS					
Obeid[86]	2005	Open gastric bypass	925	51	58.8 (inc 29% developing seromas)	39.8	0	78	–	–	–	–	–
Sosa[100]	2004	Lap RYGB	550	48.8	2.8 (over 12 months)		1	65	–	–	–	–	–
Higa[101]	2001	Lap RYGB	1500	Range 35–78	14.8		3	69	69	62	–	–	–
Rutledge[87]	2001	Lap mini-gastric bypass	1274	47	5.2		1	68	77	–	–	–	–
Pories[79]	1995	Open gastric bypass	608	49.7	25.5	B_{12} def (40%), anaemia (40%), hernia (23.9%), depression (23.4%), dumping (70.6%)	9	–	70	–	–	58	55 (10 years); 49 (14 years)
Scopinaro[59]	1998	Biliopancreatic diversion	1356	47	6.8	Anaemia (40%), stomal ulcer (6%), bone demineralisation (6%)	9	–	74	–	75	–	75 (6 years); 76 (8 years); 77 (10 years); 78 (12 years)
Biron[102]	2004	Biliopancreatic diversion + duodenal switch (in 962 cases)	1271	48.4	NS	NS	12	–	–	–	–	–	68.6 (7.2 years)
Anthone[68]	2003	Biliopancreatic diversion + duodenal switch	701	52.8	2.9	NS	10	69	–	74.7	–	67.2	–
Urbain and Heiderich[103]	2001	Vertical banded gastroplasty	893	41.5	15.3 (inc 10.8% seroma)	24.6	1	N.S.					

BMI, body mass index; EWL, excess weight loss; LAGB, laparoscopic gastric banding; RYGB, Roux-en-Y gastric bypass.

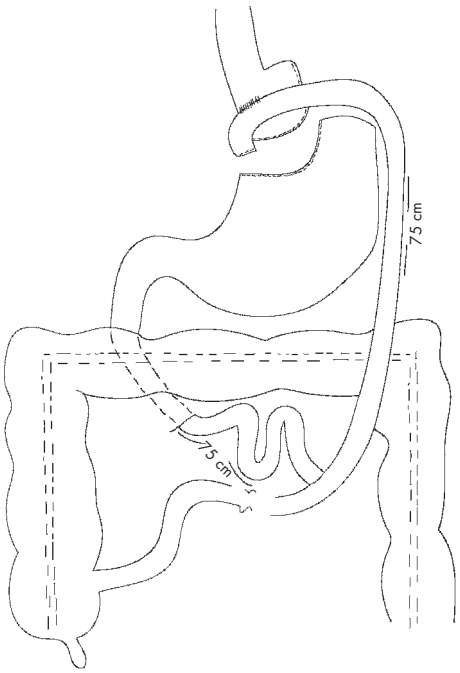

Figure 5 Roux-en-Y gastric bypass procedure.

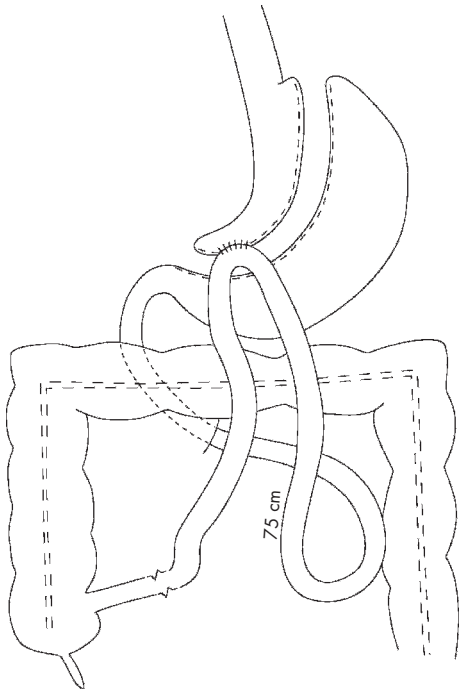

Figure 6 Mini-gastric bypass.

thromboembolic and respiratory complications. These benefits are partially negated by the increased leakage rate and notably longer general anaesthesia. The proven efficacy of gastric bypass has ensured that it remains the most popular intervention in the US.

Mini-gastric bypass

A new development is the laparoscopic mini-gastric bypass procedure, a modification of the older loop gastrojejunostomy. It involves the formation of a long gastric tube approximately 1.5 cm to the left of the lesser curvature of the stomach from the antrum to the angle of His and then a loop gastroenterostomy is formed, about 200 cm from the ligament of Treitz (fig 6). The procedure takes up to 150 min, depending on experience,[87 88] and requires conversion in 0.3% of cases. Duration of hospital stay is 2–5 days, with a return to normal activities after 1 week.[87–89]

Laparoscopic mini-gastric bypass procedure has been shown to achieve EWL of >70% at 2 years, equivalent to RYGBP,[89] but long-term data are not yet available.[89 90] In addition, it carries a mortality of <0.1%, anastomotic leak rate of <0.1%, lower risk of thromboembolic and pulmonary complications, and achieves comorbidity resolution in >70% of patients.

It is a simpler and easier laparoscopic procedure to perform than RYGBP; however, long-term data are still needed to determine whether it can match RYGBP in terms of sustained weight reduction, and also whether there is an increased incidence of long-term complications such as biliary reflux, marginal ulceration and reflux oesophagitis.

Concluding comparison of surgical techniques

Morbid obesity is associated with increased prevalence of multiple metabolic, physiological and psychological abnormalities. All of these markedly reduce the lifespan of this increasing section of the population. Surgery is effective not only at reducing weight, but also at resolving associated comorbidities while improving patients' quality of life.

All of the techniques described above help achieve marked weight loss in morbidly obese patients. Table 1 lists the largest available published case series of bariatric procedures. At present there is considerable interest in LAGB; results in table 1 confirm the relative safety of LAGB, with only a few studies reporting perioperative mortality. Excess weight loss seems to reach a peak in most studies at 2–3 years, and in three studies remains at over 50% after 5 years. The procedure is also easier to perform compared with gastric bypass. Although gastric bypass operations do have the potential to achieve greater weight loss, this benefit is tempered by increased mortality and morbidity. Further, the procedure is technically demanding and surgeons must pass a learning curve before embarking on performing it. In this respect, the laparoscopic mini-gastric bypass may be an easier alternative, although the procedure is still in its infancy, with long-term weight loss data not yet available and the risk of as yet unknown longer-term complications.

Vertical banded gastroplasty is now generally of historical interest, with few centres performing large numbers. This procedure has an unacceptable complication rate, which has led to its widespread disuse. Biliopancreatic diversion, however, may still have a role, particularly in the cohort of patients who have unsatisfactory results from restrictive surgery. This relatively invasive and complex procedure can now be safely executed laparoscopically.[91] It can induce substantial weight loss in the long term, but should be considered primarily in the super obese and in those who cannot tolerate food intake restriction but will accept long-term follow-up by a multidisciplinary team.

SELF-TEST QUESTIONS: TRUE (T)/ FALSE (F); ANSWERS AFTER THE REFERENCES

1. Morbid obesity is defined as a body mass index of >35 kg/m^2
2. Surgery to treat obesity is recommended only for patients with a BMI >40 kg/m^2
3. Pharmacological treatment combined with lifestyle intervention is a more effective method of producing sustained weight loss than surgery

4. Surgery to induce weight loss improves or resolves 90% of obesity related comorbidities
5. Biliopancreatic diversion (BPD) is a restrictive procedure
6. Roux-en-Y gastric bypass (RYGBP) is a combination of restriction and malabsorption
7. Protein-calorie malnutrition is a rare complication of BPD
8. Complication and mortality are ordered (highest to lowest): BPD–RYGBP–VBG–LAGB
9. Excess weight loss rates are ordered (highest to lowest): VBG–BPD–RYGBP–LAGB
10. LAGB achieves gradual weight loss reaching parity with RYGBP at ⩾5 years

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Competing interests: None.

REFERENCES

1 **Deitel M**. Overweight and obesity worldwide now estimated to involve 1.7 billion people. *Obes Surg* 2003;**13**:329–30.
2 **Luyckx FH**, Scheen AJ, Lefebvre PJ. Non-alcoholic steatohepatitis. *Lancet* 1999;**354**:1298–9.
3 **Sullivan M**, Karlsson J, Sjostrom L, *et al*. Swedish obese subjects (SOS)—an intervention study of obesity. Baseline evaluation of health and psychosocial functioning in the first 1743 subjects examined. *Int J Obes Relat Metab Disord* 1993;**17**:503–12.
4 **Dixon JB**, Dixon ME, O'Brien PE. Depression in association with severe obesity: changes with weight loss. *Arch Intern Med* 2003;**163**:2058–65.
5 **Knowler WC**, Barrett-Connor E, Fowler SE, *et al*. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med* 2002;**346**:393–403.
6 **Padwal R**, Li SK, Lau DC. Long-term pharmacotherapy for obesity and overweight. *Cochrane Database Syst Rev* 2003;(4):CD004094.
7 **McTigue KM**, Harris R, Hemphill B, *et al*. Screening and interventions for obesity in adults: summary of the evidence for the U.S. Preventive Services Task Force. *Ann Intern Med* 2003;**139**:933–49.
8 **Li Z**, Maglione M, Tu W, *et al*. Meta-analysis: pharmacologic treatment of obesity. *Ann Intern Med* 2005;**142**:532–46.
9 **Padwal R**, Li SK, Lau DC. Long-term pharmacotherapy for overweight and obesity: a systematic review and meta-analysis of randomized controlled trials. *Int J Obes Relat Metab Disord* 2003;**27**:1437–46.
10 **Derosa G**, Cicero AF, Murdolo G, *et al*. Efficacy and safety comparative evaluation of orlistat and sibutramine treatment in hypertensive obese patients. *Diabetes Obes Metab* 2005;**7**:47–55.
11 **Torgerson JS**, Sjostrom L. The Swedish Obese Subjects (SOS) study—rationale and results. *Int J Obes Relat Metab Disord* 2001;**25**(Suppl 1):S2–4.
12 **Sjostrom CD**, Peltonen M, Wedel H, *et al*. Differentiated long-term effects of intentional weight loss on diabetes and hypertension. *Hypertension* 2000;**36**:20–5.
13 **Silecchia G**, Perrotta N, Boru C, *et al*. Role of a minimally invasive approach in the management of laparoscopic adjustable gastric banding postoperative complications. *Arch Surg* 2004;**139**:1225–30.
14 **Buchwald H**, Avidor Y, Braunwald E, *et al*. Bariatric surgery: a systematic review and meta-analysis. *JAMA* 2004;**292**:1724–37.
15 **Sjostrom CD**, Peltonen M, Sjostrom L. Blood pressure and pulse pressure during long-term weight loss in the obese: the Swedish Obese Subjects (SOS) Intervention Study. *Obes Res* 2001;**9**:188–95.
16 **Spivak H**, Hewitt MF, Onn A, *et al*. Weight loss and improvement of obesity-related illness in 500 U.S. patients following laparoscopic adjustable gastric banding procedure. *Am J Surg* 2005;**189**:27–32.
17 **Christou NV**, Sampalis JS, Liberman M, *et al*. Surgery decreases long-term mortality, morbidity, and health care use in morbidly obese patients. *Ann Surg* 2004;**240**:416–24.
18 **Mason EE**. Vertical banded gastroplasty for obesity. *Arch Surg* 1982;**117**:701–6.
19 **Morino M**, Toppino M, Bonnet G, *et al*. Laparoscopic adjustable silicone gastric banding versus vertical banded gastroplasty in morbidly obese patients: a prospective randomized controlled clinical trial. *Ann Surg* 2003;**238**:835–42.
20 **Sugerman HJ**, Starkey JV, Birkenhauer R. A randomized prospective trial of gastric bypass versus vertical banded gastroplasty for morbid obesity and their effects on sweets versus non-sweets eaters. *Ann Surg* 1987;**205**:613–24.
21 **MacLean LD**, Rhode BM, Forse RA. Late results of vertical banded gastroplasty for morbid and super obesity. *Surgery* 1990;**107**:20–7.
22 **Alper D**, Ramadan E, Vishne T, *et al*. Silastic ring vertical gastroplasty—long-term results and complications. *Obes Surg* 2000;**10**:250–4.
23 **Baltasar A**, Bou R, Arlandis F, *et al*. Vertical banded gastroplasty at more than 5 years. *Obes Surg* 1998;**8**:29–34.
24 **Suter M**, Jayet C, Jayet A. Vertical banded gastroplasty: long-term results comparing three different techniques. *Obes Surg* 2000;**10**:41–7.
25 **Belachew M**, Legrand MJ, Defechereux TH, *et al*. Laparoscopic adjustable silicone gastric banding in the treatment of morbid obesity. A preliminary report. *Surg Endosc* 1994;**8**:1354–6.
26 **Dixon AF**, Dixon JB, O'Brien PE. Laparoscopic adjustable gastric banding induces prolonged satiety: a randomized blind crossover study. *J Clin Endocrinol Metab* 2005;**90**:813–19.
27 **Fisher BL**. Comparison of recovery time after open and laparoscopic gastric bypass and laparoscopic adjustable banding. *Obes Surg* 2004;**14**:67–72.
28 **Dolan K**, Hatzifotis M, Newbury L, *et al*. A comparison of laparoscopic adjustable gastric banding and biliopancreatic diversion in superobesity. *Obes Surg* 2004;**14**:165–9.
29 **Zinzindohoue F**, Chevallier JM, Douard R, *et al*. Laparoscopic gastric banding: a minimally invasive surgical treatment for morbid obesity: prospective study of 500 consecutive patients. *Ann Surg* 2003;**237**:1–9.
30 **Fielding GA**, Rhodes M, Nathanson LK. Laparoscopic gastric banding for morbid obesity. Surgical outcome in 335 cases. *Surg Endosc* 1999;**13**:550–4.
31 **O'Brien PE**, Dixon JB, Brown W, *et al*. The laparoscopic adjustable gastric band (Lap-Band): a prospective study of medium-term effects on weight, health and quality of life. *Obes Surg* 2002;**12**:652–60.
32 **Belachew M**, Belva PH, Desaive C. Long-term results of laparoscopic adjustable gastric banding for the treatment of morbid obesity. *Obes Surg* 2002;**12**:564–8.
33 **Vertruyen M**. Experience with Lap-band system up to 7 years. *Obes Surg* 2002;**12**:569–72.
34 **Fielding GA**. Laparoscopic adjustable gastric banding for massive superobesity (> 60 body mass index kg/m2). *Surg Endosc* 2003;**17**:1541–5.
35 **Steffen R**, Biertho L, Ricklin T, *et al*. Laparoscopic Swedish adjustable gastric banding: a five-year prospective study. *Obes Surg* 2003;**13**:404–11.
36 **Angrisani L**, Furbetta F, Doldi SB, *et al*. Results of the Italian multicenter study on 239 super-obese patients treated by adjustable gastric banding. *Obes Surg* 2002;**12**:846–50.
37 **Frigg A**, Peterli R, Peters T, *et al*. Reduction in co-morbidities 4 years after laparoscopic adjustable gastric banding. *Obes Surg* 2004;**14**:216–23.
38 **Parikh MS**, Shen R, Weiner M, *et al*. Laparoscopic bariatric surgery in super-obese patients (BMI>50) is safe and effective: a review of 332 patients. *Obes Surg* 2005;**15**:858–63.
39 **O'Brien PE**, Dixon JB. Lap-band: outcomes and results. *J Laparoendosc Adv Surg Tech A* 2003;**13**:265–70.
40 **Weiner R**, Blanco-Engert R, Weiner S, *et al*. Outcome after laparoscopic adjustable gastric banding—8 years experience. *Obes Surg* 2003;**13**:427–34.
41 **Angrisani L**, Furbetta F, Doldi SB, *et al*. Lap Band adjustable gastric banding system: the Italian experience with 1863 patients operated on 6 years. *Surg Endosc* 2003;**17**:409–12.
42 **Biertho L**, Steffen R, Ricklin T, *et al*. Laparoscopic gastric bypass versus laparoscopic adjustable gastric banding: a comparative study of 1,200 cases. *J Am Coll Surg* 2003;**197**:536–45.
43 **Mognol P**, Chosidow D, Marmuse JP. Laparoscopic gastric bypass versus laparoscopic adjustable gastric banding in the super-obese: a comparative study of 290 patients. *Obes Surg* 2005;**15**:76–81.
44 **Jan JC**, Hong D, Pereira N, *et al*. Laparoscopic adjustable gastric banding versus laparoscopic gastric bypass for morbid obesity: a single-institution comparison study of early results. *J Gastrointest Surg* 2005;**9**:30–41.
45 **O'Brien PE**, Dixon JB, Laurie C, *et al*. A prospective randomized trial of placement of the laparoscopic adjustable gastric band: comparison of the perigastric and pars flaccida pathways. *Obes Surg* 2005;**15**:820–6.
46 **Chevallier JM**, Zinzindohoue F, Douard R, *et al*. Complications after laparoscopic adjustable gastric banding for morbid obesity: experience with 1,000 patients over 7 years. *Obes Surg* 2004;**14**:407–14.
47 **Fielding GA**, Ren CJ. Laparoscopic adjustable gastric band. *Surg Clin North Am* 2005;**85**:129–40.
48 **DeMaria EJ**. Laparoscopic adjustable silicone gastric banding. *Surg Clin North Am* 2001;**81**:1129–44.
49 **Dargent J**. Esophageal dilatation after laparoscopic adjustable gastric banding: definition and strategy. *Obes Surg* 2005;**15**:843–8.
50 **Nehoda H**, Weiss H, Labeck B, *et al*. Results and complications after adjustable gastric banding in a series of 250 patients. *Am J Surg* 2001;**181**:12–15.
51 **Mortele KJ**, Pattijn P, Mollet P, *et al*. The Swedish laparoscopic adjustable gastric banding for morbid obesity: radiologic findings in 218 patients. *Am J Roentgenol* 2001;**177**:77–84.
52 **Hauri P**, Steffen R, Ricklin T, *et al*. Treatment of morbid obesity with the Swedish adjustable gastric band (SAGB): complication rate during a 12-month follow-up period. *Surgery* 2000;**127**:484–8.
53 **Weber M**, Muller MK, Michel JM, *et al*. Laparoscopic Roux-en-Y gastric bypass, but not rebanding, should be proposed as rescue procedure for patients with failed laparoscopic gastric banding. *Ann Surg* 2003;**238**:827–34.
54 **Shen R**, Dugay G, Rajaram K, *et al*. Impact of patient follow-up on weight loss after bariatric surgery. *Obes Surg* 2004;**14**:514–19.
55 **Mognol P**, Chosidow D, Marmuse JP. Laparoscopic conversion of laparoscopic gastric banding to Roux-en-Y gastric bypass: a review of 70 patients. *Obes Surg* 2004;**14**:1349–53.
56 **Cottam DR**, Nguyen NT, Eid GM, Schauer PR. The impact of laparoscopy on bariatric surgery. *Surg Endosc* 2005;**19**:621–7.
57 **Griffen WO Jr**, Young VL, Stevenson CC. A prospective comparison of gastric and jejunoileal bypass procedures for morbid obesity. *Ann Surg* 1977;**186**:500–9.

58 **Requarth JA**, Burchard KW, Colacchio TA, *et al.* Long-term morbidity following jejunoileal bypass. The continuing potential need for surgical reversal. *Arch Surg* 1995;**130**:318–25.
59 **Scopinaro N**, Adami GF, Marinari GM, *et al.* Biliopancreatic diversion. *World J Surg* 1998;**22**:936–46.
60 **Hess DS**, Hess DW. Biliopancreatic diversion with a duodenal switch. *Obes Surg* 1998;**8**:267–82.
61 **Marceau P**, Biron S, Bourque RA, *et al.* Biliopancreatic diversion with a new type of gastrectomy. *Obes Surg* 1993;**3**:29–35.
62 **Tataranni PA**, Mingrone G, Raguso CA, *et al.* Twenty-four-hour energy and nutrient balance in weight stable postobese patients after biliopancreatic diversion. *Nutrition* 1996;**12**:239–44.
63 **Hess DS**, Hess DW, Oakley RS. The biliopancreatic diversion with the duodenal switch: results beyond 10 years. *Obes Surg* 2005;**15**:408–16.
64 **Scopinaro N**, Marinari GM, Camerini G. Laparoscopic standard biliopancreatic diversion: technique and preliminary results. *Obes Surg* 2002;**12**:362–5.
65 **Scopinaro N**, Gianetta E, Adami GF, *et al.* Biliopancreatic diversion for obesity at eighteen years. *Surgery* 1996;**119**:261–8.
66 **Marceau P**, Hould FS, Simard S, *et al.* Biliopancreatic diversion with duodenal switch. *World J Surg* 1998;**22**:947–54.
67 **Slater GH**, Fielding GA. Combining laparoscopic adjustable gastric banding and biliopancreatic diversion after failed bariatric surgery. *Obes Surg* 2004;**14**:677–82.
68 **Anthone GJ**, Lord RV, DeMeester TR, *et al.* The duodenal switch operation for the treatment of morbid obesity. *Ann Surg* 2003;**238**:618–28.
69 **Brolin RE**, Leung M. Survey of vitamin and mineral supplementation after gastric bypass and biliopancreatic diversion for morbid obesity. *Obes Surg* 1999;**9**:150–4.
70 **Chapin BL**, LeMar HJ Jr, Knodel DH, *et al.* Secondary hyperparathyroidism following biliopancreatic diversion. *Arch Surg* 1996;**131**:1048–53.
71 **Hamoui N**, Chock B, Anthone GJ, *et al.* Reversal of duodenal switch: indications, technique and outcome. *IFSO Abstr Obes Surg* 2005;**15**:957.
72 **Regan JP**, Inabnet WB, Gagner M, *et al.* Early experience with two-stage laparoscopic Roux-en-Y gastric bypass as an alternative in the super-super obese patient. *Obes Surg* 2003;**13**:861–4.
73 **Mason EE**, Ito C. Gastric bypass in obesity. *Surg Clin North Am* 1967;**47**:1345–51.
74 **Nguyen NT**, Goldman C, Rosenquist CJ, *et al.* Laparoscopic versus open gastric bypass: a randomized study of outcomes, quality of life, and costs. *Ann Surg* 2001;**234**:279–91.
75 **MacLean LD**, Rhode BM, Forse RA, *et al.* Surgery for obesity—an update of a randomized trial. *Obes Surg* 1995;**5**:145–50.
76 **Olbers T**, Fagevik-Olsen M, Maleckas A, *et al.* Randomized clinical trial of laparoscopic Roux-en-Y gastric bypass versus laparoscopic vertical banded gastroplasty for obesity. *Br J Surg* 2005;**92**:557–62.
77 **Sugerman HJ**, Londrey GL, Kellum JM, *et al.* Weight loss with vertical banded gastroplasty and Roux-Y gastric bypass for morbid obesity with selective versus random assignment. *Am J Surg* 1989;**157**:93–102.
78 **Sugerman HJ**, Kellum JM, Engle KM, *et al.* Gastric bypass for treating severe obesity. *Am J Clin Nutr* 1992;**55**(2 Suppl):560S–566S.
79 **Pories WJ**, Swanson MS, MacDonald KG, *et al.* Who would have thought it? An operation proves to be the most effective therapy for adult-onset diabetes mellitus. *Ann Surg* 1995;**222**:339–52.
80 **Raftopoulos I**, Ercole J, Udekwu AO, *et al.* Outcomes of Roux-en-Y gastric bypass stratified by a body mass index of 70 kg/m^2: a comparative analysis of 825 procedures. *J Gastrointest Surg* 2005;**9**:44–53.
81 **Schwartz RW**, Strodel WE, Simpson WS, *et al.* Gastric bypass revision: lessons learned from 920 cases. *Surgery* 1988;**104**:806–12.
82 **Bessler M**, Daud A, DiGiorgi MF, *et al.* Adjustable gastric banding as a revisional bariatric procedure after failed gastric bypass. *Obes Surg* 2005;**15**:1443–8.
83 **Podnos YD**, Jimenez JC, Wilson SE, *et al.* Complications after laparoscopic gastric bypass: a review of 3464 cases. *Arch Surg* 2003;**138**:957–61.
84 **Marema RT**, Perez M, Buffington CK. Comparison of the benefits and complications between laparoscopic and open Roux-en-Y gastric bypass surgeries. *Surg Endosc* 2005;**19**:525–30.
85 **DeMaria EJ**. Is gastric bypass superior for the surgical treatment of obesity compared with malabsorptive procedures? *J Gastrointest Surg* 2004;**8**:401–3.
86 **Obeid F**, Falvo A, Dabideen H, *et al.* Open Roux-en-Y gastric bypass in 925 patients without mortality. *Am J Surg* 2005;**189**:352–6.
87 **Rutledge R**. The mini-gastric bypass: experience with the first 1,274 cases. *Obes Surg* 2001;**11**:276–80.
88 **Lee WJ**, Yu PJ, Wang W, *et al.* Laparoscopic Roux-en-Y versus mini-gastric bypass for the treatment of morbid obesity: a prospective randomized controlled clinical trial. *Ann Surg* 2005;**242**:20–8.
89 **Wang W**, Wei PL, Lee YC, *et al.* Short-term results of laparoscopic mini-gastric bypass. *Obes Surg* 2005;**15**:648–54.
90 **Rutledge R**. Similarity of Magenstrasse-and-Mill and mini-gastric bypass. *Obes Surg* 2003;**13**:318.
91 **Paiva D**, Bernardes L, Suretti L. Laparoscopic biliopancreatic diversion: technique and initial results. *Obes Surg* 2002;**12**:358–61.
92 **Szold A**, Abu-Abeid S. Laparoscopic adjustable silicone gastric banding for morbid obesity: results and complications in 715 patients. *Surg Endosc* 2002;**16**:230–3.
93 **Dargent J**. Laparoscopic adjustable gastric banding: lessons from the first 500 patients in a single institution. *Obes Surg* 1999;**9**:446–52.
94 **Favretti F**, Cadiere GB, Segato G, *et al.* Laparoscopic banding: selection and technique in 830 patients. *Obes Surg* 2002;**12**:385–90.
95 **Cadiere GB**, Himpens J, Hainaux B, *et al.* Laparoscopic adjustable gastric banding. *Semin Laparosc Surg* 2002;**9**:105–14.
96 **Ceelen W**, Walder J, Cardon A, *et al.* Surgical treatment of severe obesity with a low-pressure adjustable gastric band: experimental data and clinical results in 625 patients. *Ann Surg* 2003;**237**:10–16.
97 **Fernandez AZ Jr**, Demaria EJ, Tichansky DS, *et al.* Multivariate analysis of risk factors for death following gastric bypass for treatment of morbid obesity. *Ann Surg* 2004;**239**:698–703.
98 **McCarty TM**, Arnold DT, Lamont JP, *et al.* Optimizing outcomes in bariatric surgery: outpatient laparoscopic gastric bypass. *Ann Surg* 2005;**242**:494–501.
99 **Shikora SA**, Kim JJ, Tarnoff ME, *et al.* Laparoscopic Roux-en-Y gastric bypass: results and learning curve of a high-volume academic program. *Arch Surg* 2005;**140**:362–7.
100 **Sosa JL**, Pombo H, Pallavicini H, *et al.* Laparoscopic gastric bypass beyond age 60. *Obes Surg* 2004;**14**:1398–401.
101 **Higa KD**, Ho T, Boone KB. Laparoscopic Roux-en-Y gastric bypass: technique and 3-year follow-up. *J Laparoendosc Adv Surg Tech A* 2001;**11**:377–82.
102 **Biron S**, Hould FS, Lebel S, *et al.* Twenty years of biliopancreatic diversion: what is the goal of the surgery? *Obes Surg* 2004;**14**:160–4.
103 **Urbain P**, Heiderich B. Six years experience with minilaparotomy silastic ring vertical gastroplasty. *Obes Surg* 2001;**11**:258–64.

ANSWERS

1. T; 2. F, patients with a BMI >35 kg/m^2 with one of the comorbidities listed in table 1, or with a BMI >40 kg/m^2 with or without comorbidity; 3. F; 4. T; 5. F; 6. T; 7. F; 8. T; 9. F, BPD>RYGBP>LAGB/VBG; 10. T